SECTION 7: EFFECTS OF TWO UWB SIGNALS ON THREE FEDERAL RADARS

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7.1 Introduction

Some UWB signals appear to occupy a relatively large portion of the spectrum when compared to the spectral occupancy of the signals of conventional systems. This leads to the notion that UWB systems may need to share the same spectrum with conventional incumbents. As in the case where two conventional systems share spectrum, questions are raised about the effects of a new system sharing spectrum with an incumbent. NTIA conducted the following study to determine the levels at which a UWB signal could be present within a radar receiver.

The study involved two types of UWB signals. Both types of UWB signals consisted of pulses at a 10 MHz pulse repetition rate (PRR). Both types had the same pulse shape and amplitudes. The first signal type was dithered using pulse position modulation over 50% of its basic repetition rate. In other words, there was a basic repetition interval of 100 ns. Each pulse was delayed from 0 ns to 50 ns within each interval. The position for each pulse was determined by a uniformly distributed random number generator. The second signal type was not dithered; the pulses were generated at a constant rate. The non-dithered signal produces spectral lines which have a frequency spacing equal to the reciprocal of the pulse rate. Since the pulse rate used in this study was greater than the receiver's bandwidth, for the case of the non-dithered signal, only a single spectral line was present within the receiver's passband.

Three Federal Aviation Administration (FAA) radio receivers were involved in the testing: the Air Route Surveillance Radar (ARSR-4), the Airport Surveillance Radar (ASR-8) and the Air Traffic Control Beacon Interrogator (ATCBI-5). The ARSR-4 is a long range radar that detects targets up to 518 kilometers away. The ASR-8 assists with traffic control at airports and detects targets up to 124 kilometers away. The ATCBI-5 transmitter interrogates transponders that are located on aircraft, while its receiver detects and processes the responses from the aircraft transponders. All three of these receivers are located at the FAA Mike Monroney Aeronautical Center (MMAC) in Oklahoma City, Oklahoma.

7.2 Radiated Measurements

The radiated measurements involved radiating a signal over a line-of-sight path from the UWB source to the receiver under test. The levels, relative to the receiver's noise floor, were measured

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and recorded. The results of this study will assist with determining any effects on these receivers if their spectrum is shared with UWB devices. The radars at the MMAC are good representations of radars that are operating in the field. These radars are fully functional but they are not being used to generate the critical information needed by air traffic controllers. The receivers are connected to rotating antennas that are the same as the field units. The FAA uses these radars to test new concepts before implementing the concepts on all their units and to train new personnel.

To conduct this study, the following approach was implemented. A measurement vehicle was outfitted to record the received signal level from an operating radar while the vehicle was in motion. A GPS unit was installed in the vehicle. The measurement started on the road next to the radar. The starting location was stored as a way point in the GPS receiver. The GPS receiver was set to display the distance and bearing from the vehicle to the radar. The vehicle was driven along roads that approximated radials from the transmitter. When a peak in the signal level occurred, the distance and bearing to the radar were recorded.

The results from the various runs were examined to identify the locations in which the maximum signal level was received. By reciprocity, these locations would offer the best chances for seeing any effects that the UWB transmitter would have on the receivers. The results showed that the signal level right under the radar was not the maximum level. Radar antennas typically concentrate their radiated energy into narrow beams. This is necessary for them to determine bearing and range to a target. These beams are directed into the sky to detect airborne craft. The lowest angle of interest for the beam is usually slightly above the horizon. The area under and close to the antenna is not directly illuminated by the beam, so only a moderate signal level exists. An example of this is shown in Figure 7.1. For approximately the first 1.75 horizontal divisions, the signal is relatively undefined with rapid variations. After 1.75 horizontal divisions, the spikes are well defined and vary smoothly.

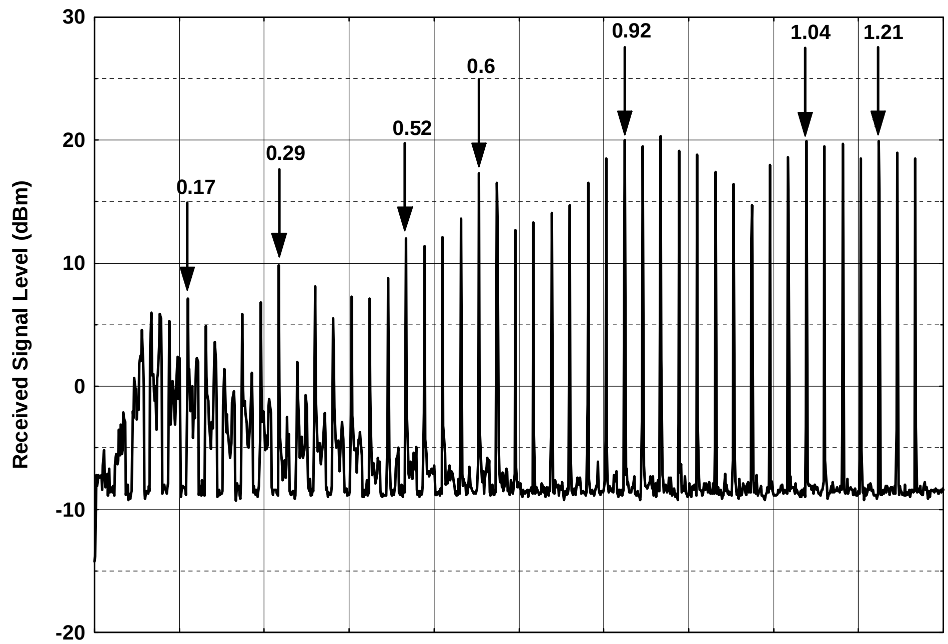

Figure 7.1. ARSR-4 signal level along a southern radial.

Foliage and buildings are other factors that influence the received signal level. When either of these obstructions enter the line-of-sight path between the vehicle and the radar, the received signal level drops rapidly and a good sample at that distance is lost. The measurements were conducted over several approximately radial paths in an attempt to get samples over a large number of distances.

Once the locations of highest signal level were known, the next part of the study took place. The Intermediate Frequency (IF) output of the radar receiver under test was connected to the spectrum analyzer. The noise level on the spectrum analyzer was noted at the expected IF frequency before connection to the IF output. All the levels were measured with the spectrum analyzer resolution bandwidth set to 1 MHz and the video bandwidth set to 10 Hz. This is the same spectrum analyzer settings that are used in a FCC Part 15 compliance measurement for frequencies above 1 GHz. The spectrum analyzer was connected to the receiver's IF output and the noise level was noted again. It was necessary for the noise coming from the IF receiver to raise the noise floor of the spectrum analyzer a perceptible amount in order for the measurements to be valid. This was the case for all of the receivers in this study.

The measurement vehicle was configured to house the UWB transmitter. A ridged horn antenna was mounted on a telescoping mast on the vehicle. While measurements were being conducted, the horn antenna was elevated above the vehicle roof to prevent reflections. For each measurement, the UWB transmitter was adjusted, by a variable attenuator, to produce an effective isotropic radiated power of -41 dBm. This level corresponds to the radiated emission limits found in FCC Part 15.209 for frequencies above 1 GHz.

The measurement vehicle was parked near some of the locations of highest signal level as well as a few others. It usually was not possible to pull off the road right where a peak occurred. The horn antenna was raised and pointed at the radar under test and the UWB transmitter was activated. The radar transmitter was then turned off and its antenna was manually pointed in the azimuth of the vehicle. The antenna was swung through many degrees to find the peak delta marker value, which was recorded. The delta marker value consists of setting a reference level with the UWB transmitter off, then measuring the decibel increase in the level with the UWB transmitter on. Various attenuator settings were tried. The attenuator settings and the resulting delta marker values were recorded.

In addition to the UWB transmitter measurements, a few incidental radiators were activated, with line-of-sight paths to the radars, at the above sites. The delta marker values due to these devices were recorded. This shows a comparison between UWB sources and incidental radiators.

7.2.1 ARSR-4 Radiated Measurements

The ARSR-4 receiver frequency was 1241.47 MHz. The PRR for the non-dithered UWB signal had to be adjusted to put a spectral line within the passband of the receiver. It was calculated that if the PRR was increased by 10.01 kHz, this would put a spectral line at 1241.241 MHz. This new PRR was used for this radar.

The vehicle was driven along two paths. One path was along a southern radial that started at the radar. The received signal level along this path is shown in Figure 7.1. The graph is labeled with the distances from the radar in kilometers where the peaks occurred. The second path was on a southern path that started 0.64 kilometers west of the radar. The received signal level along this path is shown in Figure 7.2. On this graph, there is a gap in time, because the vehicle was stopped and some time passed before the recording resumed. Although the vehicle was driven at a constant speed and in most cases distances can be interpolated between the marks on the graph, one should not interpolate across the gap in time.

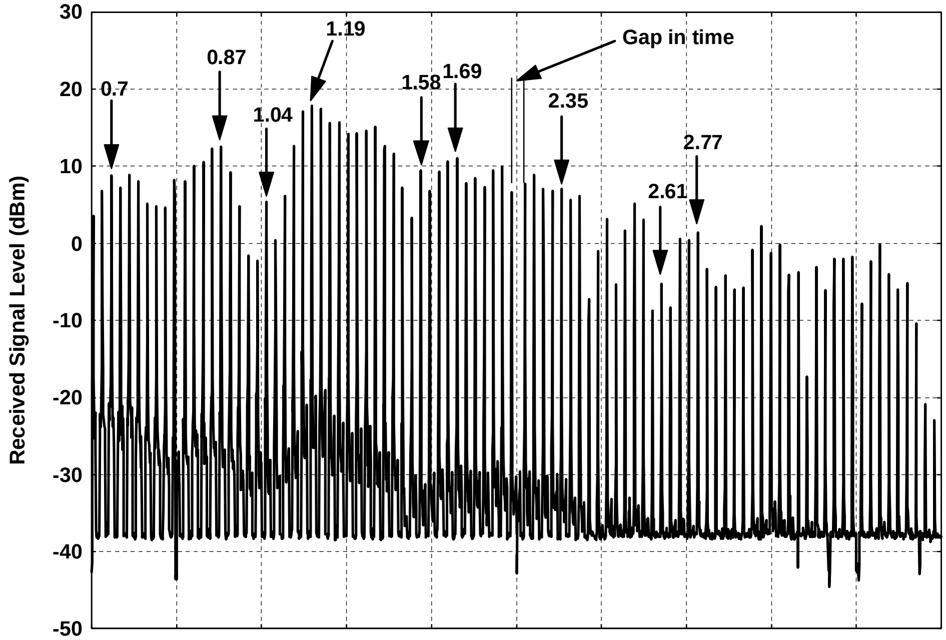

Figure 7.2 ARSR-4 signal level along a southern path.

Next, the vehicle was driven to three sites where measurements were performed. The first site was 1.26 kilometers from the radar at a bearing of 178 degrees. For a 10 MHz PRR dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 9 dB. Attenuating the UWB transmitter output by 6 dB brought the delta marker value down to 6 dB. Attenuating the UWB transmitter output by 12 dB brought the delta marker value down to 2 dB. Attenuating the UWB transmitter output by 15 dB brought the delta marker value down to 1 dB. For the non-dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 0 dB. In this case, the UWB signal did not affect the noise floor. An electric drill and an electric shaver were turned on to see if their radiation could be observed at the receiver's IF. The electric shaver produced asynchronous spikes 10 to 15 dB above the noise floor but this did not affect the noise floor. This is shown in Figure 7.3. The electric drill did not affect the noise floor.

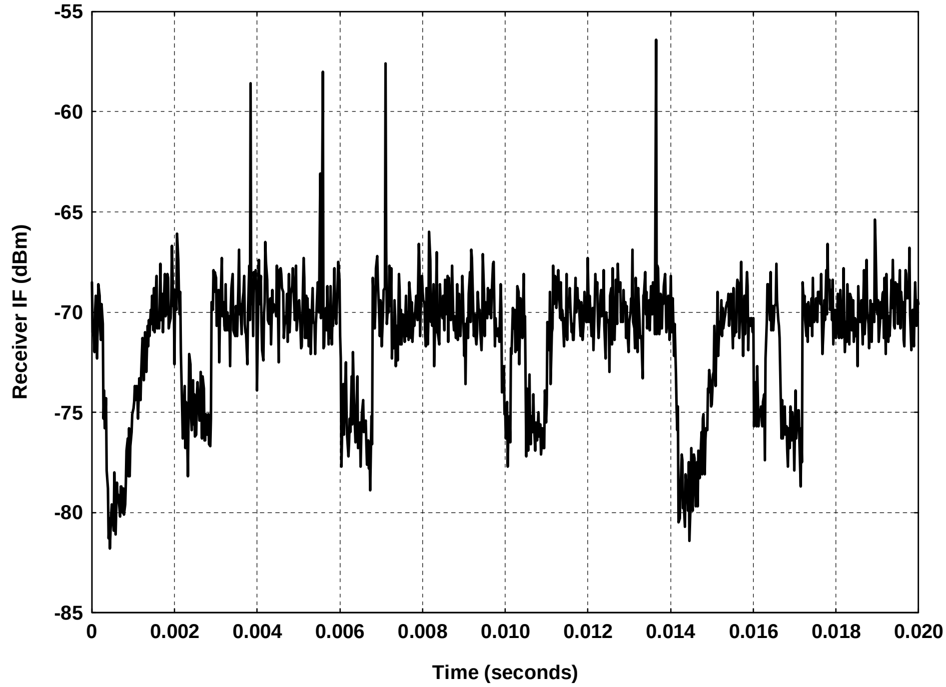

Figure 7.3. Asynchronous spikes produced by the electric shaver.

The second site was 2.08 kilometers from the radar at a bearing of 199 degrees. For a 10 MHz PRR dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 11 dB. Attenuating the UWB transmitter output by 6 dB brought the delta marker value down to 8 dB. Attenuating the UWB transmitter output by 12 dB brought the delta marker value down to 4 dB. Attenuating the UWB transmitter output by 18 dB brought the delta marker value down to 2 dB. For the non-dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 0 dB. In this case, the UWB signal did not affect the noise floor. An electric drill and an electric shaver were turned on to see if their radiation could be observed at the receiver's IF. Neither item affected the noise floor.

The third site was 3.17 kilometers from the radar at a bearing of 53 degrees. For a 10 MHz PRR dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 8 dB. Attenuating the UWB transmitter output by 6 dB brought the delta marker value down to 5 dB. Attenuating the UWB transmitter output by 12 dB brought the delta marker value down to 2 dB. Attenuating the UWB transmitter output by 15 dB brought the delta marker value down to 1 dB. For the non-dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 0 dB. In this case, the UWB signal did not affect the noise floor. An electric drill and an electric shaver were turned on to see if their radiation could be observed at the receiver's IF. Neither item affected the noise floor.

For a dithered UWB signal, radiated at the FCC Part 15.209 radiated emission limit, the maximum delta marker value was 11 dB. For a non-dithered UWB signal, radiated at the FCC

Part 15.209 radiated emission limit, the maximum delta marker value was 0 dB.

7.2.2 ASR-8 Radiated Measurements

To find the locations of highest signal level, the vehicle was driven along three paths. One path started at the radar, went west for 0.22 kilometers, then went north. The received signal level along this path is shown in Figure 7.4. The second path was on a northern radial that started approximately 0.48 kilometers northeast of the radar. The received signal level along this path is shown in Figure 7.5. The third path was a northward extension of the first path. This path started 0.78 kilometers northwest of the radar and went north. The received signal level along this path is shown in Figure 7.6. On this graph, there is a gap in time, because the vehicle was stopped and some time passed before the recording resumed. Although the vehicle was driven at a constant speed and in most cases, distances can be interpolated between the marks on the graph, one should not interpolate across the gap in time.

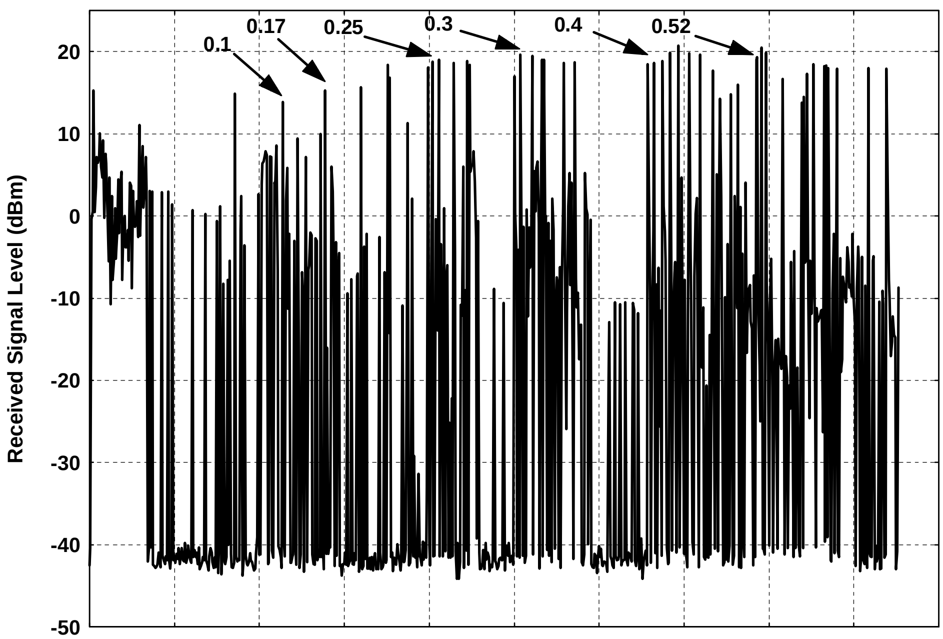

Figure 7.4. ASR-8 signal level along a mostly northern path.

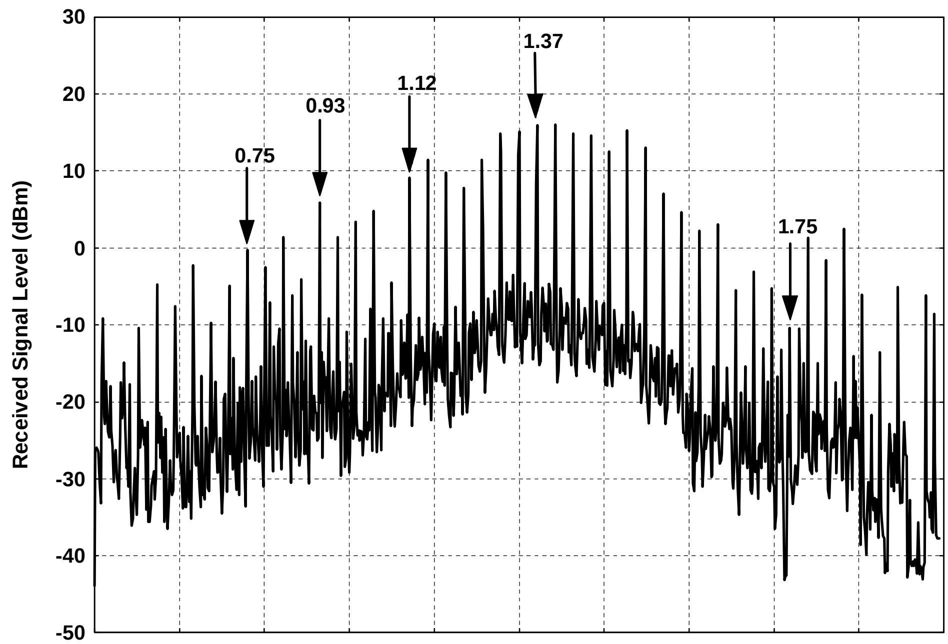

Figure 7.5. ASR-8 signal level along a northern radial.

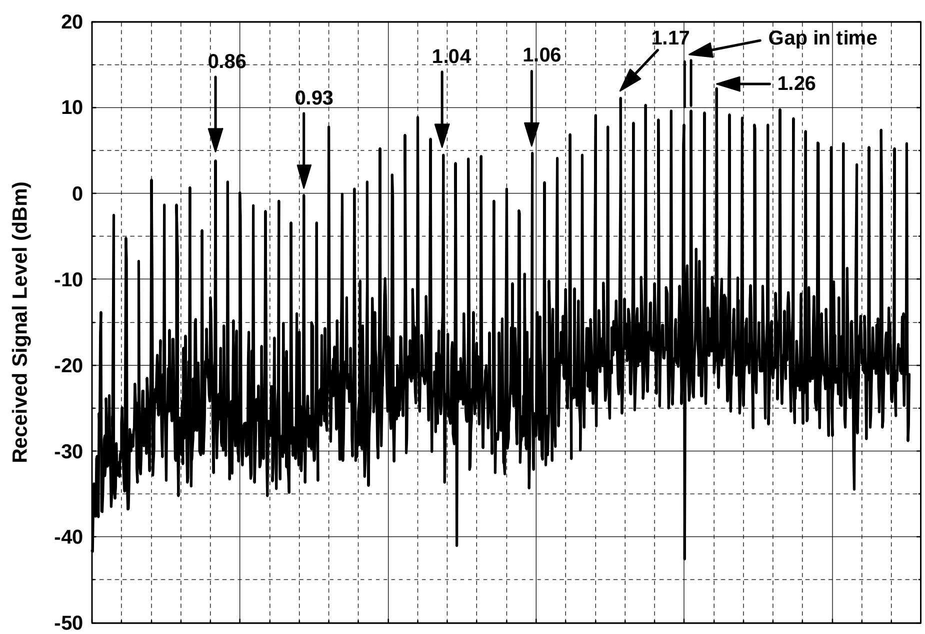

Figure 7.6. ASR-8 signal level along a northern extension of figure 7.4.

Next, the vehicle was driven to two sites where measurements were performed. The two sites were located as close to a recorded signal peak as possible. The first site was 0.4 kilometers from the radar at a bearing of 326 degrees. For a 10 MHz PRR dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 6 dB. Attenuating the UWB transmitter output by 3 dB brought the delta marker value down to 3 dB. For the non-dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 5 dB. Attenuating the UWB transmitter output by 3 dB brought the delta marker value down to 2 dB. An electric drill, electric hair dryer and an electric shaver were turned on to see if their radiation could be observed at the receiver's IF. These items did not affect the noise floor.

The second site was 1.41 kilometers from the radar at a bearing of 11 degrees. For a 10 MHz PRR dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 1 dB. For the non-dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 3 dB. Attenuating the UWB transmitter output by 2 dB brought the delta marker value down to 2 dB. An electric drill, electric hair dryer and an electric shaver were turned on to see if their radiation could be observed at the receiver's IF. These items did not affect the noise floor.

For a dithered UWB signal, radiated at the FCC Part 15.209 radiated emission limit, the maximum delta marker value was 6 dB. For a non-dithered UWB signal, radiated at the FCC Part 15.209 radiated emission limit, the maximum delta marker value was 5 dB.

7.2.3 ATCBI-5 Radiated Measurements

This radar at this location is mounted on top of a 30.5 meter tower. Because the typical ASR beacon installation is not this high, these measurements may give rather optimistic results. If the UWB signal was seen by this configuration, then the typical configuration would probably see the signal at a higher level.

The vehicle was driven to two sites where measurements were performed. The first site was 1.26 kilometers from the radar at a bearing of 178 degrees. For a 10 MHz PRR dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 0 dB. For the non-dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 0 dB. An electric drill and an electric shaver were turned on to see if their radiation could be observed at the receiver's IF. These items did not affect the noise floor.

The second site was 0.5 kilometers from the radar at a bearing of 178 degrees. For a 10 MHz PRR dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 1 dB. For the non-dithered signal, radiated at the FCC Part 15.209 radiated emission limit, the delta marker value was 0.6 dB. An electric drill and an electric shaver were turned on to see if their radiation could be observed at the receiver's IF. These items did not affect the noise floor.

For a dithered UWB signal, radiated at the FCC Part 15.209 radiated emission limit, the maximum delta marker value was 1 dB. For a non-dithered UWB signal, radiated at the FCC Part 15.209 radiated emission limit, the maximum delta marker value was 0.6 dB.

While the vehicle was parked 15.2 meters from this radar, an electric drill and an electric shaver were turned on to see if their radiation could be observed at the receiver's IF. These items did not affect the noise floor.

7.3 Summary

It is instructive to gather the results into tables for examination. Table 7.1 contains the delta marker values for the dithered UWB signal. Table 7.2 contains the delta marker values for the dithered UWB signal. All of the values correspond to the cases where the UWB signal is radiated at the FCC Part 15.209 radiated emission limit. The results indicate that all three radars experience a noticeable effect for at least one and in some cases, both types of UWB signals that were generated in this study. The ARSR-4 presented an interesting case in two ways. Within the constraints of three site testing, Table 7.1 shows a relatively large effect with a dithered signal and Table 7.2 shows no effect with a non-dithered signal.

Table 7.1. Delta Marker Values in Decibels for the Dithered UWB Signal.

Radar	First Site	Second Site	Third Site
ARSR-4	9	11	8
ASR-8	6	1	
ATCBI-5	0	1	

Table 7.2. Delta Marker Values in Decibels for the Non-Dithered UWB Signal.

Radar	First Site	Second Site	Third Site
ARSR-4	0	0	0
ASR-8	5	3	
ATCBI-5	0	.6	